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ECOLOGICAL ASPECTS OF CAGE CULTURE OF FISH

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WORKSHOP ON FLOATING CAGES AND NET PEN ENCLOSURES

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on

ECOLOGICAL ASPECTS OF CAGE CULTURE OF FISH

by

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This Review paper is a working document which will be subject to subsequent revision.

Abstract

This paper attempts to summarize the various biological aspects which have to be considered in selecting fish for cultivation in floating pen or fixed enclosures. The experiences of various operations with temperate and tropical fish in the confined cultures of sea, estuaries, lakes, reservoirs and rivers are referred to. Guiding principles to be observed as well as criteria for choosing fish and adapting enclosures for the type of fish to be grown are indicated. Operational biological investigations and problems are reviewed while precautionary measures and the useful application of these enclosures are mentioned. A small selection of references of literature which deal with the above aspects is provided.

Introductory

For some decades the use of pen-enclosures and cages have been of increasing interest as a practical means of fish production and as efficient experimental devices. Cageculture systems have become a traditional system in many countries of Asia and in one form or another has been practised in Africa and Latin America. Cageculture for experimental and subsequently commercial aquaculture in the highly developed economies of Europe and North America has now become widespread. These systems have, however, evolved through a combination of circumstances in which there has been an accommodation relative to the habits of the fish cultivated and the design of the various enclosures used. If these proven methods are therefore to be applied in other countries with their indigenous species, then some prior biological considerations should be recognized.

In this paper an attempt is made to indicate some of these factors which involve the ecology of the net enclosure, the choice of fish for the netpen system and possible modifications in the design of the enclosure in relation to the specific biology and behaviour of the fishes to be cultivated. A review of selected available literature which indicates some of these considerations has been made. This is by no means an exhaustive summary, it provides only an indicative account of major factors involved in healthy survival and efficient growth of the fish.

2. General Principles

Enclosures are used for growing fish in the sea, estuaries, reservoirs, lakes and rivers where waters are saline, brackish, or fresh. The location of the pen is governed by protective physical conditions, water quality, movement, access, and control as well as by "bio-mass carrying capacity" of the water and the types of fishes which are to be reared. Each situation requires specific consideration. Systems that apply at sea will not necessarily be suitable for lakes, for example.

The consequences of site selection must be considered from the viewpoint of biological affects on the fish, e.g. their ability to withstand changes in water conditions, the degree of fouling or other influences external to the confined area. Changes in estuaries are quite considerable with wide variations in salinity and levels through rains or tides. Freshwater environments may be less variable but having seasonal changes of temperature, oxygen, and naturally available food due to rains or sunlight penetration during dry weather and cloudy seasons. Flood levels must be considered.

For any water area concerned, a knowledge of the cycle of environmental changes, the critical periods of chemical or physical conditions and the general effect on the confined fish are needed. Experimentation and data monitoring of changes as they occur can indicate the critical tolerance (determined beforehand) limits for the fish and avoid disastrous losses in such enclosures.

The procedure for pen-enclosures is somewhat similar to keeping fish in an aquarium (whether salt or fresh water) and such aquarium experience with the species is most useful. While in the aquarium the water and fish are under deliberate observation and management, with cages management is only possible through regular sampling. Similarly observations are less visible. The general principles of pond culture of the species apply with certain modifications. The objective of culture or growth of fish in pens, cages or fixed enclosures is the profitable production of a captive population of fish which can be marketed for food. The concentrations of fish must necessarily be greater than those which are found in the wild or natural state of waters and even of a fish culture pond.

3. Ecology of the enclosure

In the wild, fish move freely to select environments or ecological niches which are favourable for feeding, healthy growth, survival and breeding; wherever conditions are adverse they move out of the area. In enclosures the fish has no such choice! It is therefore essential to maintain the best conditions for growth and survival. If the operation is to be economically practical it has to be biologically sound within tolerance ranges of fish.

Physical conditions include: temperature, light penetration shade or hiding shelter, currents or water flowage rates, depth and substrata which are normally preferred.

Chemical conditions include: oxygen, salinity, pH/alkalinity which are ideal for the fish. (Industrial plant wastes or hot water discharges in waters with cages are to be avoided.)

Biological factors include (see also section 4) initial size for stocking of fish (at which its handling and toughness give good survival), stocking density, resistance to disease, docility or irritability in confinement, food requirements and ecological preferences for combination with other species.

If the enclosure is floating at the surface, suspended in the middle depth or fixed at the bottom, the environmental choices offered to the confined fish are different. When enclosures are singly placed, freer exchange of water is possible than when they are in groups, rows or in a crowded locality. The requirement of particular fish for natural food and the type of that food, apart from the additional feeds that are provided, will limit the carrying capacity and effective stocking density. The productivity role of bottom sediments (in enclosures which give fish access to the bottom) is significant with regard to food production, sanitation and nest building. The role of epiphytic growth and of bio-fouling organisms attached to the cage has also to be considered.

Finally, the conditions in the waters external to the enclosure can adversely affect fish health.

This may include polluting discharges or waves from the passage of vessels which may cause stress and excite or disturb the fish.

Frequent monitoring of conditions within and outside the enclosure, particularly in the directionof flow of the stream or tides, and careful examination of samples of fish in the cage can help pre-empt critical conditions which can cause mass mortality or total kills in cages.

By establishing, beforehand, critical survival limits for various environmental factors such as BOD or oxygen, temperatures, salinity, pH for the fish being cultivated , safety measures can be taken when such critical survival limits are being approached. In many cases mortality may be due to a number of factors and not a single direct influence. The inter-relation of various factors which can cause stress, debilitate the fish and allow diseases or parasites to overwhelm them should be closely studied and understood as far as possible. Safe limits are generally well below thelethal limits in say BOD. Sub-lethal limits can also create weakened conditions through physiological stress, during which period it is easier for parasites to have an effect or for microbial infection to supervene. Safe limits should therefore be those which are closest to the optimum for the species. The fish must be allowed to grow well, not barely survive!

Aeration of the water by forced circulation in the vicinity of the cages has been practised in several countries. Various aerators have been used, including the "upwelling fountain" type and the paddle-wheel aerator. The paddle-wheel system is highly efficient for aerating densely stocked ponds as it creates a current stream which can remove metabolites as well as increase the dissolved oxygen available to the captive fish. The passage of powered vessels in rivers may also create a similar effect for the oxygenation of the waters of crowded cages.

4. Choice of fish for different enclosures

Criteria: When observing local conditions for each fish considered for culture the following assessments, determined in the natural habitat of the fish, may be useful:

a) "Toughness" or "hardiness" - adaptability to close confinement, handling and crowding.
b) Behaviour - suitability for enclosure culture of given design.

c) Ecological niche - preference for bottom, middle or surface dwelling, light or shelter.

d) Biology - food habits, growth rates, breeding, size at maturity.

e) Physiological limits - oxygen, temperature, pH, salinity, water flowage requirements.

This is a rough guide in selecting fish suitable for pen cultures. The fish must have a high market value and adapt well to confinement. It may be then further investigated through practical tests with specimens of different sizes tested in standard type cages in different localities and depths to assess performance.

Some practical hints:

-<u>Size for stocking in cages</u>: The weight of the fish at which it is hardy or tough enough to withstand handling, crowding and environmental change must be tested experimentally. (Organs must be sufficiently developed in their functioning to make biological adjustments in the event of changes in water condition, e.g. tidally or through current flow in a river or through diurnal oxygen changes in eutrophic reservoir or lagoon waters). This may be used as the minimum initial stocking size for the enclosure.

-<u>Life history studies</u>: As complete knowledge as possible of growth rate behaviour and aquaculture suitability of the species. Selection of species singly or combined; and suitable sites for such culture. When the minimum tough handling size is determined, the size for most rapid growth should also be determined.

-<u>Robustness</u>: Fish which are generally free of parasites or disease and are hardy and not susceptible to mortality or infections during handling or close confinement are good candidates for cage culture.

-<u>Docility</u>: Compatibility with other fish species in close confinement; the fish should also be not too readily excitable or prone to stress, jumping and shock.

-<u>Food habits</u>: Fish used in cage enclosures may be herbivorous, plankton feeders, omnivorous, carnivorous, and detritus or bottom feeders.

Silver and Bighead carps and milkfish are well-known examples of plankton feeders; while common carp is well used in Indonesia as a detritus and omnivorous "karamba" occupant. Yellowtail, groupers and catfish are the carnivorous types commonly used in Asia. Some cage systems are designed to be self-providing of the fishes' food requirements. In most cases, however the stocking density of fishes now requires that much additional feeds be given to obtain good growth. Accordingly, many pelleted feeds have been formulated and used in cage culture. This often involves the use of timed automatic feeders and demand feeders, many models of which are available. The critical issue is, however, the type and composition of pellet feeds and their nutritional efficiency. In the case of predatory species, protective shelters within the cage and fish of one size should be used and careful observation made for any signs of cannibalism.

The objective is rapid efficient growth of fish. It is essential to determine the type, quantity, time and frequency of delivery of additional feed and the relation of feed to growth of fish and conversion rates in different water temperatures. It is better to give a little less than satiation levels than to overfeed and increase costs; further, excess food will increase BOD and attract predators or pests. There is much literature for certain fish feeds, particularly for catfish and trout.

If proper diets are given and fish are not interested in food, it may indicate a beginning health problem. Monitoring of weight increases and conversion factors are necessary to ensure a good level of production. Knowledge of average mortality levels or cause of mortality of any specimens should be investigated. Very intensive concentrations of fish are generally involved; therefore, losses through fish kills can be disastrous.

Compatability in food habits and ecological niches could permit combinations of plankton feeders with detritus feeders or omnivores. Such polyculture systems are highly productive.

-Behaviour: The manner in which they swim and their adaptation to human presence and handling are important factors for smaller enclosures. Ability of a fish to adjust to the confinement of a cage may make one species more desirable than another for cageculture. Does bumping of the cage frighten or disturb the fish? (trout and catfish). How do the fish behave; do they swim continuously in schools or do they rest and hide? Do they show a distinct pattern of movement, e.g. trout swim counter-clockwise in a circular pattern around cages when feeding. It should be noted that under excessive physical, environmental or osmotic stress fish are easily subject to bacterial or fungal diseases. Such stress can be occasioned in some species by mal-adjustment to their confined area and by frequent disturbance.

Selection of fish from the wild is best started with younger, more adaptable members of the species since irritability of newly caught adult fish is far greater, and younger fish can be more readily accustomed, by feeding, to human interference. Shelters may be important for bottom dwelling or nocturnally moving fish; stocking density and oxygen requirements for newly collected specimens may be critical for survival in cages.

-Breeding: The cage is used mainly for grow-out or food production. Best growth or feed conversion is obtained before juveniles reach maturity. Normally the rate of growth slows down as the gonads

gonads develop and with the onset of spawning. Generally it is undesirable that the fish should spawn in the cages. In some cases, however, nest building at the bottom or the laying of adhesive eggs on the hard surfaces of enclosures or even the release of pelagic eggs can take place in cages. It should be noted that floating cages with large mesh sizes (to permit the flow through of water and avoid the accumulation of sediments)can prevent the breeding of Tilapia in confinement.

Various types of enclosures are also effectively used for segregating mating fish. Additionally, cages are excellent tools for replicate experimental cultures in a single pond.

5. Designing enclosures for selected fish

The design, shape and dimensions of a cage in relation to the species being cultured is of critical significance. The mesh size of netting, grill or fence must be small enough to prevent escapement of fish but large enough to permit free passage and exchange water. The depth and size is a function of the fish type and habit (surface, mid or bottom dweller, jumper, etc.) and screens often cover the surface to avoid jumping out or attack by predatory birds. Fouling and sediments attract predators and crabs which destroy the net. The nets should therefore be designed and constructed to make them easily handled for cleaning.

From the various designs and construction models, one should consider their suitability for the different fish for which they can be used. The initial size of meshes will be small to contain the juvenile first stocks and larger mesh sizes will be used as the fishes grow. Similarly, the numbers initially in a cage will vary as the fish grow.

The effective dimensions of the cage will be a matter for operational convenience. Is it intended that it should be operated by one or two persons? Will it require mechanical operation for harvesting or cleaning of the webbing when it becomes fouled with encrusting growth? Operational practices indicate that industrial operation use a smaller functional unit with high yields in Europe and N. America, while larger enclosure pens are used in Asia.

It may also be best to determine the most practical size of cage according to the quantity (and weight of fish required at harvesting) which would be most convenient for sales and transport from each unit enclosure. This dimension, in conjunction with the manpower available for handling the unit, is probably the best guide for a functional size. Larger units though involving less capital investment per ton of fish produced, will require much more skill in management and are greater risks for loss of stock. Many small units rather than a large unit may seem preferable.

Since such matters as sampling, disease, monitoring as the fish grow and eventual harvesting have to be constantly kept in mind, a small initial size of enclosure may be most practical for ease of control. A large enclosure requires a large investment and may need many fish, much food supply, skill, and efficiency for profitable operation. Again, any losses due to adverse conditions can be a major deterrent to further effort.

It should be noted that cage design, location, feeding, size of fingerlings stocked, and their density are thus inter-related. For successful results, all of these must be closely watched.

6. Cage site selection

Site selection criteria include:
-good water quality (pollution free)
-storm and wave protection
-easy monitoring access for management and sampling
-stable water temperatures
-current flowage
-minimum bio-fouling (if possible)
-minimum predation/interference

In North America the practice of fattening cattle on the feed lot in preference to the grazing range is well-known. The cage technique similarly concentrates the fish in a limited space to minimize space, labour and materials and utilize pelleted feed. The cage is sited so that tidal currents can provide a continuous flushing exchange of water through the knotless net-pens. This ensures a supply of oxygenated water and dilutes and/or removes excretory wastes to a large extent. The fouling growth on the netting may also help to retain wastes and impede the free passage of water through the pens. Apart from the locality and their siting with regard to currents, depth, etc. it will be evident in practical operations that too close an assembly or even double lines rather than single rows of cages can so impede water passage as to affect both the cleansing/oxygenation role of water flowage and to encourage growth organisms.

Often critical situations occur when the environment becomes too crowded and beyond the tolerance limits of the captive fish. Experiences of total kills in some localities involve heavy operational losses to owners. In selecting a site, some thought should be given to what maximum number of cages can be safely operated there. The condition of captive fish should be carefully monitored when that density of cages is being reached.

7. Operational Biology

Cageculture has been shown in many countries to be a biologically and economically sound way of rearing certain fish. An analysis of the biological principles which have been applied in practice may indicate what has to be deliberately researched for new species in their normal indigenous locality, when adapting them to this technique. Some criteria have been mentioned with the selection of suitable fish species. Once decided, there are some specific determinations that have to be made. These include: the initial stocking size; the rate of growth expected in the enclosure; the stocking density - singly or in polyculture combinations; the quantity and composition of additional food to be given; the nature and control of bio-fouling organisms; the monitoring of "water quality" and of epizootics.

(i) Growth rates: An essential operation in cageculture management is the regular collection of samples of fish for a quick weighing and examination. The rate of growth of fish in the cage is then measured by weighing samples of fish. (At the same time their condition, vitality, activeness, lesions or external parasites may also be observed.) These assessments, together with observations made during feeding or when changing nets or when monitoring bio-fouling are important biological assessments to indicate the performance of the captive fish in an enclosure. It is an essential procedure in starting cage culture experiments and it must be a routine practice as the investigations develop into a commercial scale operation. Without such biological monitoring, it is difficult to establish adequate data and experience with new species as a guide for extension operations.

If monoculture of species is being practised, then it may be useful to try growing two different size classes which are compatible. It may be better perhaps to choose different species - polyculture or combination culture in which one species benefits from the food which the other does not eat.

(ii) Stocking densities: The maximum density of a given species (in kgs. per cubic metre) which can be grown in a given cage needs to be determined experimentally. Rate of growth and feed conversion should be studied in comparison to stocking densities and total weights for a given size of fish once the design, shape, dimension and best location of the cage have been determined. The maximum weight of fish per unit of enclosed water which will not result in a reduction of growth rate or food conversion must be established. A safe lower limit must then be used to avoid stress due to other factors which singly or in combination can consequently cause debilitation, disease and mortality to result progressively.

In certain cases (Kilambi) it has been shown that within stated limits cage size and stocking density had little effect on growth or feed conversion or condition factor for trout and channel catfish but that the higher initial weight of the fish at stocking was a more critical factor in determining rapid growth in cages. The precise implications for any particular indegenous species may be usefully investigated when determining the most appropriate and effective size for stocking in enclosures.

High densities or crowded stocking of cages can increase the incidence of fin wear and infections. Fish may easily bruise themselves when rushing if frightened in the pens. High densities can also reduce growth rate or feed conversion efficiency.

(iii) Food. Any enclosure has a certain amount of naturally available food which the fish will utilize. In the case of plankton feeders, the passage of water through a well situated cage may bring adequate quantities of phyto- and zoo- plankton if the fish numbers are not too great. Such a situation is well illustrated in Singapore's eutrophic Seletar reservoir where certain locations are more favourable than others for a given density of fish and number cages. Similarly the "karambas" in Indonesia require little additional food because of the rich benthic population in the bottom of the river on which the cages rested. On the other hand the experience of cages in Lake Bonut and Lake Calibatan, near San Pablo, have shown that it is possible to overstock cages beyond the trophogenic capacity of a lake's waters.

Even with highly eutrophic waters there is therefore a balance that must be determined and maintained if the plankton feeding fish are to grow well and the enterprise is to be profitable. Other types of fish will require supplemental feeding. However, to satisfy the nutritional requirements of the captive fish it is often necessary to provide additional feed. There are many pelleted rations formulated on the basic chicken feed and varied both in size and composition for various fish at different ages. Such feeds have to be given according to the daily requirements and conversion efficiency of the size group of captive fish. Feeds are often given through automatic feeders which dispense given quantities of feed daily. Tests have shown that carp will eat more than they can efficiently convert to weight gain if given all they can eat.

(13) Accordingly, it is preferable to feed to below satiation point. The provision of feeds and the stimulated production of natural food require careful attention in the case of new species being tried in enclosures.

(iv) Bio-fouling organisms. Depending on sea or inland conditions and on the material netting used for enclosure i.e. synthetic net or metal screening, the fouling may be of different intensity and type of organism. The interaction of the fouling organisms with the fish being cultivated needs to be considered. Methods of removing the bio-fouling will also depend on the type and age of such organisms. Frequency of cleaning will effect the stress condition and survival of fish. A few types of fouling organisms occurring in sea conditions are:

Algae - *Ectocarpus* sp. mixed with diatoms and desmids *Enteromorpha* sp., *Scytosiphon* sp., *Cladophora* sp. *Ulva* sp. *Ceramium* sp.

Hydroids - *Tubularia* sp.

Sea squirts - *Ascidiella* sp. *Ciona* sp.

Nudibranchs - *Facelina* sp.

Cirripeds - *Balanus*

Sponges - *Grantia* sp.

Mussels - *Mytilus* sp.

Seaweeds - *Laminaria*.

It should be appreciated that the netting offers a very attractive attachment surface for growth of any sessile forms of plants or animals bathed with a rich nutrient medium so their growth could be rapid. The control of such growth by the insertion in the cage of "grazing" fish, shrimp, or snails has been one of the polyculture solutions. The maintenance of a relatively clean mesh is essential for water flowage exchange to ensure healthy growth of the enclosed fish. Circular cages which rotate to expose the fouling organisms and submerge a cleaner section are being used in Europe.

The rate of accumulation of bio-fouling organisms should be studied, the sequence and identity of attaching organisms determined, and effective means of controlling or removing them undertaken. This is essential for efficiant cageculture production. The encrustation also reduces the floatation of the cage and traps silt and fish excreta. Milne has indicated that such encrustation of bio-fouling can increase the weight of nets from 3 to 10 times and that galvanised welded mesh showed minimum fouling and was effective with fish. (7)

(v.) Water quality monitoring. This is well illustrated in Chua's paper. (2) The freshwater environment is no less complex. Plankton blooms oxygenation and CO_2 saturation, depending on bright sunny days or overcast cloudy days, may result in inadequate oxygen levels for fish survival. Blooms of diatoms and bluegreen algae have been particularly hazardous in shallow eutrophic lakes such as Laguna de Bay, resulting in fish kills. High stocking density of enclosures placed in such waters are therefore to be avoided. Similarly the number of enclosures should not be so great as to approach the critical limit of the carrying capacity of the water body when the limiting factor of BOD may be provoked by weather conditions and thus cause fish kills.

(vi.) Predators may be aquatic, aerial or amphibious animals. Double nets or perimeter nets to surround the cages are generally effective for sharks and larger predatory fish. Smaller predators may come in as young or enter through holes in the webbing. Clean, rigid nets help to avoid attracting crabs or predatory fish which damage nets and thus allow fish escapement. Poles with suspended aerial nets are evidently best to keep off predatory birds. Noise makers eventually prove ineffective. Guard dogs on floating pontoons are effective deterrents to other types of interference.

(vii.) Fish Health Maintenance. With low stocking density in cages and normal water conditions, fish held in enclosures can thrive in a healthy state. Problems occur when the equilibrium is upset i.e. when large numbers create stressful environmental conditions; when food is deficient in some of the requirements of the growing fish; when BOD or water quality are unfavourable for the fish; when epizootics pervade the system and the vitality of the fish cannot resist them or when the favourable survival conditions are unbalanced by changes consequent upon bio-fouling, changes in current, etc.

Stress weakens the fish and makes it susceptible to diseases or infections which result in individual or mass mortality. Lowered levels of dissolved oxygen, sudden temperature changes can also distress (if not kill) fish promptly. When conditions have resulted in the death of any fish, it may be too far advanced to avoid major losses. Symptoms of stress and unusual behaviour of the fish are thus to be considered as a serious indication of trouble to be diagnosed and relieved. The main conditions in the design, location and operation of the cage which resulted in successful initial survival should be reviewed to see what altered conditions may have contributed to the distress of the fish.

Frequent observation of cages for unusual behaviour (erratic swimming, jumping, cannibalism, etc.) is essential. Regular sampling of the fish in the cages will disclose evidence of parasites, lesions, fin rot etc. When the net enclosure is changed for cleaning or examined for bio-fouling it should then be possible to find more evidence of fish deaths or critical indications. The regular sampling of fish for growth and feed conversion assessments is the important time to check on the condition of fish and undertake preventative measures to avoid increasingly critical conditions. Two cases are cited below as examples experienced with warm water and temperature cage cultures. (11 and 5, 8).

Parasitic infectation

In warm waters with high fish density and presence of metabolites and cage incrustations, the chances for disease infestation is considerable and must be monitored. Steffens (11) recorded the occurence of ectoparasites which seemed to "invade" the cages and then disappear. *Argulus*, *Piscicola*, *Trichodina* and *Gyrodactylus* were collected from infected fish and either through bath treatments or flow changes the infestation was controlled. Such ectoparasites or gill parasites can also cause lesions which result in secondary and fungal infections of weakened fish.

Bacterial and fungal diseases are more prevalent in temperate climates where the fish are held for a longer growing season. Harrell, Novotny, and other authors describe some of the infections that occur in pen-reared salmon. (5,8) Vibriosis, caused by the marine pathogen *Vibrio anguillarum*, has been found to cause high mortality among salmon in saltwater pens during warmer summer months at higher temperatures (15°C) and when the populations of fish in the cages is high. An innoculum of bacteria prepared from heat-killed bacteria of *V. anguillarum* was used to vaccinate coho salmon successfully and control the infection.

The treatment and control of various diseases and parasites is a major subject and cannot be adequately dealt with here. The main point is a *preventative* approach, the maintenance of conditions as normal as possible to avoid disease and mortality. When these do occur, isolation of cages, removal of infected fish and the identification of the causative organism or circumstance by fish pathologists are necessary. Appropriate measures and treatments can then be undertaken.

(viii.) Harvesting. Some specific hints have been extracted from various operational experiences:

-Easiest manageable dimensions of net enclosures. (for stock supply, management controls, harvesting)

-Size at which fish should be harvested for greatest efficiency of production units, food conversion and markets.

-Year-round production/cropping possibilities.

-Efficient and practical methods of harvesting.

9. Operational factors that effect the biological balance.

Management of cage cultures involve both routine biological assessments and environmental monitoring of the locality for any changes likely to occur. Exceptional tides or adverse weather forecasts naturally require protective measures but the gradual changes due to seasonal changes have to be foreseen and their impact on the operation recognized. Cloudy days, hot seasons or severe dilution through seasonal rains may have a slight to severe or compounded influence in changing the conditions in the enclosure.

Supervisory management in Asia which often involves living on location (as in the Mekong River) permits daily observation and the prompt harvesting of the fish if unfavourable conditions are indicated or impending.

Other factors which must be considered are: effect of movements of vessels (wave action, disturbance from navigation channels, etc.); pollution effects of discharges of domestic or industrial wates; silting and sedimentation around cage culture sites. These circumstances can all have an influence on the profitability survival and growth of the captive fish. It is, therefore, necessary to consider the biological impact on the well-being of the captive fish of all the everyday activities which affect the waters in which cage enclosures are situated. If these change radically, the fish may be indirectly affected.

10. Aids and Precautionary Measures

The investment in time and money could be very considerable for cage operations. Observance of practical criteria may be the first step to successful operations and avoidance of many problems. Furthermore, if the harvest of fish is lost through fish-kills, the whole profitability of the exercise is jeopardized and is a deterrent to extension promotion of these systems. Aeration devices can increase the oxygen in the water and flush away accumulated wastes in the vicinity of cages. As a safety measure then, it may be useful to have some aeration device handy in cage experiments. Demand feeders can provide some supplementary foods and reduce supervision costs. Regular cleaning of nets can ensure good water circulation. Though expensive, perhaps the best types of webbing for the enclosure that result in limited fouling may be a worthwhile long-term investment.

11. Benefit

In general, cage culture systems involve less capital investment and recurrent costs per ton of fish produced than in pond culture. They, however, require more technical monitoring but are essentially based upon the continued maintenance of good water and environmental conditions. For cages to be successfully operated, the waters cannot be polluted. It is therefore in the interest of the owners/operators in rivers and estuaries to assist in ensuring a good water quality while local authorities, recognizing the benefits of food production, have a further incentive to prevent pollution.

Some of the profitable aspects are cited in Pantulu's paper which indicates costs and incomes obtained in some cage culture operations. (9)

An interesting application of the use of cages has been their use for the control of algal blooms in the Selatar reservoir in Singapore. Here the use of plankton feeders in cages has helped to utilize algal blooms in ~~water reservoir in Singapore.~~ Here the use of plankton feeders in cages has helped to utilize algal blooms in water reservoirs profitably.

Some other advantage of net pens systems mentioned by various authors include:

-free flowing tidal or river currents bring oxygenated or fresh waters into pens and flush out metabolic wastes so pumping water for renewal is unnecessary and cost saving.

-net pens are resilient and yield to currents.

-net pens are a lower capital investment compared with fixed structures and dyked ponds.

-net pens are movable though when installed are anchored in position. They cause less environmental change and are indices of satisfactory water conditions for fish survival.

-water temperatures in sea, reservoirs or rivers are less suddenly variable and are relatively constant compared to shallower extensive ponds.

-They provide alternative fish production methods in coastal zone and control of pollution in estuaries and mangrove lagoons.

-They permit year-round production and harvesting in quantities adjusted to market demand by small fishing enterprise.

12. Other Considerations

Other papers in the workshop and some cited here have indicated the profitability of these systems. For those who plan to undertake further experimentation with this system in new areas, and before applying the system widely, it will be important to make assessments of some of the following:

-Expected life and maintenance costs of cage enclosures with analysis of production costs (food, management, mortality losses) based on different stocking densities in the standard pen enclosure; the preferred market sizes, the ideal market times and the cost efficiency of food used.

-Numbers of pens or cages per family unit for investment/production feasibility.

Finally some of the applications of net pens and cage enclosures should be listed:

-Food fish production

-Testing water quality with index species

-Experimental fish introductions - survival, growth, adaptation

-Fish health studies

-Fish growth, feed conversion, nutrition studies

-Virtually year-round production and harvesting

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